

Industrial Applications of ECR-Based Neutron Generators

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Phoenix Nuclear Labs' (PNL) high yield deuterium-deuterium (DD) neutron generator, with measured yields greater than 3×10^{11} n/s, is based upon a proprietary gas target coupled with a custom 300 kV accelerator and a high-current microwave ion source (MWS). The ion injector is comprised of a MWS for deuterium ion generation and an extractor to produce a low emittance beam from the ion source for transport to a subsequent accelerating column. The PNL ion source utilizes 2.45 GHz microwaves and an 875 Gauss magnetic field to produce high plasma densities by generating electron cyclotron resonance (ECR) interactions. As no filaments are required to ignite the plasma, the microwave ion source can operate with long lifetimes, on the order of years. The ion extractor, which is biased negatively with respect to the plasma chamber, pulls deuterium ions from the ion source into the accelerator. PNL ion sources have been operated with extracted deuteron currents as high as 90 mA as measured by a calibrated calorimeter located downstream of the extraction aperture.

Three prototype neutron generators have been delivered: one to the US Army for neutron radiography, one to Ultra Electronics' Nuclear Control Systems for neutron flux monitor calibration, and one to SHINE Medical Technologies for medical isotope production. Experiences operating and optimizing the various subsystems (ion source, accelerator, focus element, differential pumping stages, and gas target) for each application will be described. System requirements and tradeoffs for these diverse applications, including thermal neutron radiography, medical isotope production, nuclear instrumentation testing and calibration, and explosives detection, will be presented, along with preliminary results. Multiple next-generation systems are presently being designed and constructed at PNL with an emphasis on further increasing neutron yield and reliability and on decreasing physical size, weight, and price of the system. Modifications currently underway include further increases in voltage and current, the use of a solid target (e.g. for fast neutron radiography), and transitioning to a mixed deuterium-tritium beam in the gas target system. The latter modification will result in a neutron yield increase of approximately 50X. PNL is targeting delivery of three generators with neutron yields of 5×10^{13} DT n/s in 2018 to SHINE's molybdenum-99 production facility.